Risk community profile : a tool to assess a variety of hazards on a territory

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COMMUNITY RISK PROFILE: A TOOL TO ASSESS A VARIETY OF HAZARDS ON A TERRITORY

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Communities are facing a large variety of risks that community leaders have the responsibility to manage and reduce in relation with numerous stakeholders and partners. Risk assessment is the first step of the risk management process and serves as a base for the risk reduction decisions that can have a strong impact on the territory. A detailed risk assessment is not an easy task and the decision to undertake such assessments should be based on a first simple estimate of the risk level. From a community point of view, it is also essential to be able to consider all the types of hazards to take coherent decisions and to characterise the relative contribution of each type of hazard to the global risk on the community.

It is to answer to these needs that the APELL program of UNEP has asked to INERIS to develop the community risk profile tool described in the present paper. The tool is based on a multidimensional definition of risk. Nine dimensions are considered and assessed for each of the hazard types. Risk is considered as a combination of the presence of a hazard source, the probability of the hazardous phenomena it can produce, and its intensity, the presence of vulnerable elements in the surroundings, their vulnerability, the existence of prevention and protection measures, the emergency preparedness and the resilience of the community.

The hazards considered are industrial accidents, transport of dangerous goods, flooding, volcanoes, earthquake, tsunami, landslide, forest fire, tornadoes and cyclones. For each of these hazardous phenomena, a questionnaire allows for the assessment of the nine dimensions of risk. For most of the dimensions, the assessment is based on a multicriteria approach with results expressed in a common scale ranging from 1 to 5, 1 being the most favourable situation and 5 the most unfavourable one. For some of the dimensions, namely intensity and probability, a quantitative scale can be used. The attempt was made to propose common scales, the definition of which is commented in this paper.

Examples of assessment criteria are given together with examples of the methodological difficulties encountered during this project. Some have been solved and the solutions proposed are described. Other difficulties remain open to contributions from the scientific communities but also from the stakeholders of the risk management process. The Community Risk Profile is currently under revision by UNEP experts for an expected publication in mid 2007.

INTRODUCTION

Communities are facing various types of risks, which they have to assess and manage properly. These risks may be of a human origin: industrial risks or risks related to the transport of hazardous materials. They can also be of natural origin: floods, earthquakes, volcanoes, ground movements. Many decisions should take the risk into account. Those concerning the risk management itself, of course, but also decisions such as land use planning or industrial investment.

Assessing risk is not an easy task. It requires to perform in depth studies which are only justified if the risk level is expected to be high for this reason, there is a need for a risk assessment tool that would provide the user with an information about the necessity to further assess the risk by characterising an expectable risk level on the base of a mostly qualitative approach. Such a tool, a risk community profile, was developed by INERIS for and together with the UNEP APELL program.

RISK ASSESSMENT DIMENSIONS

The aim of the tool is to provide means for communities to assess roughly various types of risks and take appropriate decisions, notably to undertake further investigations, from this initial risk assessment. For this purpose, the definition of risk was voluntarily extended from the classical combination of probability and severity to a broader definition that includes reference to the vulnerability of the area, or emergency preparedness. The community risk profile can be used to assess the initial level of risk independently of existing mitigation measures. It can also be used to assess whether the existing measures are sufficient to cover the initial risk. In any case, a high risk level should induce in depth risk assessment. The risk assessment dimensions are divided into

– hazard related dimensions: presence of hazard sources, frequency, intensity of hazardous phenomena;

– vulnerability related dimensions: presence of vulnerable elements within the effect area of the hazardous phenomena, vulnerability of the exposed elements and of the area, resilience of the area,
– risk control related dimensions: knowledge of risk (pre-existing risk assessment studies), prevention, protection, emergency preparedness.

It is important to note that we make here a clear distinction between hazard and risk. As there are many definitions of hazard in the literature, we should precise here the definition that we retained for the present work. We consider in the present paper that hazard is the combination of the likelihood and the intensity of a hazardous phenomenon. Risk is the combination of hazard and the vulnerability of the environment exposed to the potential hazardous phenomenon and of the control measures. This definition of risk is inspired by the definition proposed in the ARAMIS project [Salvi 2006]. The next paragraphs are dedicated to the description of the risk assessment dimensions or parameters. The scale in which they are expressed and the sub-parameters used for their assessment are particularly described. As several types of hazards were studied in the community risk profile, it was essential to propose a definition of risk which would fit all these hazard types and which could be assessed through a common approach. For some of the dimensions the nature of the phenomena makes the achievement of this goal not obvious. Tables 1 and 2 summarise the definitions of the components of hazard and vulnerability. They are commented more deeply in the next sections.

COMMUNITY RISK PROFILE GRAPHICAL REPRESENTATION AND COMMON SCALE

The result of the assessment done with the community risk profile is composed of two parts: the community risk profile matrix (figure 1) where all the risk assessment dimensions marks are summarised and the community risk profile graphs (figure 2), which, for each specific risk provides a graphical representation of all the risk dimensions. To be able to set up both these tools, it was necessary to define scales. The choice was made to use a common scale fort all the risk assessment parameters. All the parameters are measured in a 1 to 5 scale with always the same orientation: 1 correspond to a favourable situation, 5 to an unfavourable one. In other words 1 corresponds to a low hazard, a low level of elements at risk or vulnerability, or a sufficient level of risk control. On the other hand a 5 means a high hazard, a high level of elements at risk an insufficient control of risk. The meaning of the scales is given by figure 3.

The figure 2 represents the community risk profile graph for a given type of hazard and its interpretation. The bigger the surface area of the community risk profile, the higher the risk and the necessity to take prevention and mitigation measures. The shape of the graph is also significant and attention should be given to the meaning of each area of the graph.

Table 1. Definition of intensity and parameters taken into account for the qualitative estimation of frequency

Hazard	Source type	Intensity	Frequency
Industry	Punctual	Surface area of the reference industrial accident	Directly related with the number of plants and the quality of prevention measures
Transport of dangerous goods	Punctual	Surface area of the reference transport accident involving dangerous goods	Related with number of roads, the traffic density and the quality of the roads as well as the prevention measures
Flood	Linear	Surface area of the reference flood	Related with climatic and morphological characteristics of the area plus impact of human activities on the water flow
Earthquake	Whole community	Intensity (MSK) or magnitude (Richter) of the reference earthquake	Related with the location of the community in a seismic zone
Volcano	Punctual	Surface area of the lethal effect zone of a reference volcanic eruption	Related with the characteristics of the volcano
Hurricane	Whole community	Intensity of a reference cyclone (Saffir simpson scale)	Related with the location of the community in a hurricane prone area
Landslide	Surface	Surface area of a reference landslide	Related with morphological, geological and climatic characteristics of the area and with human activities on the area
Forest fire	Surface	Surface area of the potentially burn forest zone	Related with morphological, geological and climatic characteristics of the area and with human activities on the area
Tsunami	Linear	Surface area of the coastal zone potentially flooded by a reference tsunami	Related with the location of the community on a seashore in a tsunami prone area

Table 2. Definition of the various risk assessement dimensions for the various types of hazard considered in the community risk profile

Hazard	Intensity	Global intensity	Individual frequency	Global frequency	Individual damage	Global damage	Local risk	Global risk
Industry	Se	Se	f	Fc = f.Np	I.D.V	I.D.V	r	r.Np
Transport of dangerous goods	Se	Se	f	Fc = f.Lr.Td	I.D.V	I.D.V	r	r.Lr.Td
Flood	Se = d.L	Se = d.L	f	Fc = f.Nr	I.D.V	I.D.V	r	r.Nr
Earthquake	I	I	f	Fc = f	I.D.Sc.V	I.D.Sc.V	r	r
Volcano	Se	Se	f	Fc = f.Nv	I.D.V	I.D.V	r	r.Nv
Cyclone	I	I	f	Fc = f	I.D.Sc.V	I.D.Sc.V	r	r
Landslide	Se	Se	f	Fc = f.Nh	I.D.V	I.D.V	r	r.Nh
Forest fire	Se	Se	f	Fc = f.Nh	I.D.V	I.D.V	r	r.Nh
Tsunami	Se = d.L	Se = d.L	f	Fc = f	I.D	I.D	r	r

I = intensity of a hazardous event generated by one single source
d = distance from the source
L = length of hazard source in the community (road, river, sea shore)
f = frequency of an event for one single hazard source
Fc = frequency of the hazardous event at the community scale
D = density of vulnerable elements
V = vulnerability of the vulnerable elements
Sc = surface area of the community
Np, Nr, Nh, Nv = number of plants, rivers, hazardous spots, volcanoes

The community risk profile can be divided into three main areas:

- The upper right part correspond to the characteristics of hazard, with presence, intensity and frequency of a dangerous phenomenon.
- The lower part corresponds to the vulnerability of the community to the hazardous phenomenon
- The last part, which covers the entire left half of the community risk profile corresponds to the risk control activities.

If the upper right part has a large surface, it means that the hazard is high. Yet, it doesn't necessary mean that the risk is high as if the lower right part is small, the elements at risk and vulnerability are low and thus the risk is low too. If an

The table below is filled automatically when the spreadsheets corresopnding to each type of risk are filled

		Industry	Transport of dangerous goods	Tropical Cyclones	Flooding	Forest fires	Volcano	Earthquake	Landslide	Tsunami
Name of the corresponding area										
Presence	0-5	0	5	5	5	0	0	5	0	0
Intensity	1-5	3	2	4	4	3	1	1	4	5
Frequency	1-5	1	4	4	5	5	1	2	3	4
Elements at risk	1-5	0	0	0	0	0	0	0	0	0
Vulnerability	1-5	2	1	0	0	0	0	0	0	0
Knowledge of risk	1-5	2	4	1	5	1	1	1	1	4
Prevention	1-5	1	5	5	1	1	5	5	2	5
Protection	1-5	4	5	5	5	5	1	5	5	5
Emergency preparedness	1-5	5	5	5	5	5	5	5	5	5
Resilience	1-5	2	2	2	2	2	2	2	2	2

Figure 1. Community risk profile matrix

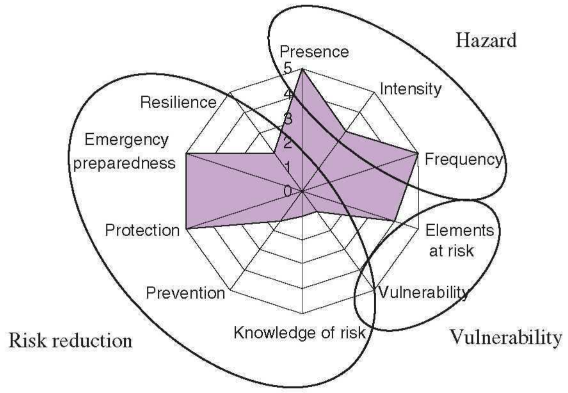

Figure 2. Community risk profile graph and its interpretation

accident occurs, it will create very limited damages. If the left part is small, it means that the risk is under control. If preventive measures are sufficient, the probability of having an accident should be low too. The next paragraphs are dedicated to the description of the risk assessment dimensions.

PRESENCE OF HAZARD SOURCES

When considering risk in a given geographical area, the first question to be asked is whether the community area bears a hazard source that would be susceptible to produce a hazardous phenomenon. For example, if no industry is present on the area or near its limits an industrial accident is not susceptible to occur. If the hazard source is not present, there is no use to assess the other dimensions. On the other hand, if one or several hazard sources are present, a risk analysis is necessary to estimate all the other dimensions of risk.

The hazard sources considered in the community risk profile are the following:

- Industrial plants including SMEs,
- Transport infrastructures: roads, railways, waterways, pipelines,
- Volcanoes,
- Rivers, as a potential source of floods,
- Slopes, where landslides can occur,
- Forest and vegetation susceptible to burn, giving rise to a wild fire,
- Sea shore, where Tsunami can occur,
- Earth as a potential source of earthquake,
- Sky from where storms and, in particular tropical cyclones, can come from.

The assessment of the presence of hazard sources is thus apparently relatively simple. Yet it requires some care because hazard sources located outside the community may cause accidental effects within the community and therefore should be taken into account. Other difficulties might be raised by the decision to select a hazard source or not. For example as far as industrial risks accidents are concerned, the question is whether all industrial plants or rather only some activities should be considered. To help the user with this specific question, a guidance list is proposed based on the IAEA guidance report on safety assessment. When useful, for other types of hazards, additional questions help the user identify situations of hazard where the presence of hazard source is not obvious.

KNOWLEDGE OF RISK: PRE-EXISTING RISK ASSESSMENT

If a hazard source is identified, it is essential that a true risk analysis be performed to obtain a true estimate of the risk. The community risk profile is only an indication of the actual risk level. It is based on average assumptions and very general criteria. If more precise results are available, they should be used to assess the risk in depth instead of the very general indications provided by the community risk profile.

Knowing the risk, i.e. analysing and assessing it, is a first essential step of risk management. It is based on risk analysis and other technical studies contributing to the risk assessment. If the knowledge of risk is insufficient, and if the community risk profile let expect that a relatively high

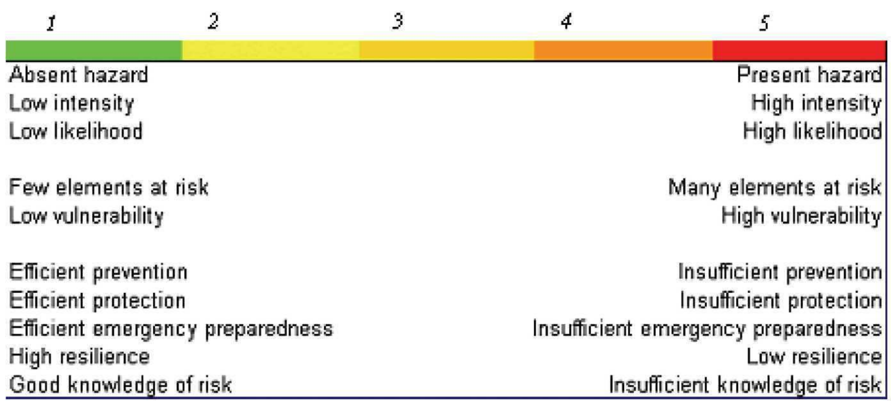

Figure 3. Interpretation of the scales

risk level is present, further studies should be undertaken to reach a satisfactory knowledge level. Knowledge of risk is thus a first dimension of risk control.

INTENSITY

If a hazard source is present, the intensity characterises the size of the potential event. As very different types of events are considered in this tool, it was important to define a common intensity scale that could be used to assess any kind of event. It was decided that there should be a direct relation between the intensity level and the damages for a given level of elements at risk and vulnerability. The common proposed intensity scale and the definition of intensity for each type of hazard correspond to this goal.

Many hazards have a point or linear origin and develop an intensity that is maximum at the origin and decreases regularly when moving away from the source. Beyond a certain level of intensity, that is above a certain distance, no effect is observed. However, the level of damage is not only related to the distance from the source but rather to the overall surface area of the impacted zone. The intensity level can then be characterised by the surface area where a given effect can be observed. For example a lethal effect. This is the definition of intensity that was chosen in the community risk profile for most of the hazard types, which have a punctual or linear source. For them, a common intensity scale was proposed (table 3). The limits between risk categories remains arbitrary and should be debated among stakeholders in the future.

For industrial risks, the tool provides an estimate of typical intensity levels for most hazardous industrial activities in terms of potentially affected surface area. This estimate is based on the IAEA Manual for the classification and prioritization of risks due to major accidents in process and related industries [IAEA 1996]. For other risks such as floods or forest fires the user is asked to estimate the potentially affected area. This information can be obtained from existing risk assessment studies or by identifying historical evidences of past events.

For the other types of risk, which have a non localised effect, the intensity level is usually characterised by an intensity indicator (wind speed for cyclones, earthquake intensity for seismic events) coherent with the most usual scales. The establishing of a correspondence between the intensity as a surface area and the intensity of non localised phenomena (cyclones, earthquake) was not easy and should be debated in the future.

Table 3. Common intensity scale

Intensity level	Corresponding surface area
1	Effect zone $<$ 0,2ha
2	0,2ha $<$ effect zone $<$ 3ha
3	3ha $<$ effect zone $<$ 12ha
4	12ha $<$ effect zone $<$ 40ha
5	40ha $<$ effect zone

Table 1 lists the various types of hazard considered in the community risk profile, the definition of their intensity and the parameters used to estimate the expected frequency.

The definition of the intensity is not without raising questions. The first one is related with the meaning of a global intensity mark for a territory. Whether the intensity, and beyond the intensity the damage level, should be absolute or relative was a matter of debate. The choice could have been made to measure the intensity as the percentage of the total community area affected by the accident. This would have corresponded to a territorial vision of the damages and translated the idea that the impact of an accident on a given community is dependent on the global size of the community (reflecting somehow its wealth), small communities being more vulnerable to the accident than big ones. This is not what was retained in the community risk profile where it was considered that the same accident occurring in two different communities should have the same intensity.

Such an approach is coherent for industrial accidents and all the punctual hazard sources for which the intensity is independent from the size of the community. It also true for cyclones and earthquake. But it doesn't work for floods and tsunami whose intensity depend directly on the length of river or seashore crossing the community. When considering the damages caused by an accident, it turns out that, whereas they remain independent from the size of the community for punctual sources, it is not the case any more for earthquake and cyclone whose damages are directly linked to the size of the community, which conditions the number of exposed vulnerable elements. Table 2 summarises the various ways to calculate the intensity and frequency of an accident in the Community risk profile and illustrates the difficulty to adopt a unique definition for all types of hazard.

FREQUENCY

The hazard, as we defined it is the combination of the likelihood (expressed in terms of probability or expected frequency) of an hazardous phenomenon and its intensity. In the case of very rare events or events that can occur only once in a given place (for example the collapse of a cliff) the probability is assessed from indirect indicators. In the case of more frequent events, the frequency can be assessed from a historical approach. The frequency is the return period of a given event. From a past frequency, it is possible to extrapolate a future expected frequency if the conditions at the origin of the past event remain true in the future (which is seldom the case).

In the community risk profile, it was decided to express the likelihood of future dread events in terms of frequency. A common frequency scale was proposed for this purpose (table 4). Again this scale should be debated between stakeholders. It was meant to allow the comparison of risks with very different frequency ranges. For example, the typical frequencies of forest fire in fire-prone areas is closer to 1/10 years whereas other events such as major industrial

Table 4. Common frequency scale

Frequency level	Frequency (events per time period)
5	1/10 years
4	1/100 years
3	1/1000 years
2	1/10000 years
1	1/100000 years

accidents can have much lower expected frequencies. Yet the estimation of frequency is far from being simple. When no pre-existing risk assessment study nor historical data is available, the assessment is based on qualitative risk criteria. The right column of table 1 provides examples of such qualitative criteria for each type of hazard.

As for the intensity, the estimation of the frequency raises questions because it may be dependent of the limits of the system studied and the reference scenario taken into account. For example, as far as the flooding risk is concerned, the use is to consider a reference flood associated with a reference return period: usually ten or hundred years. The frequency level is thus conventional and directly linked with the associated intensity. If there is only one flood source (one river) in the community, the frequency remains relatively independent from the size of the community. However, from the community point of view, the frequency of a flood is also dependent on the number of rivers in the community which is somehow dependent on the size of the community. In the same way, each industrial plant has its own accident frequency. When considering the community, the industrial accident frequency is proportional to the number of plants and is thus dependent on the size of the community. Frequency is therefore very dependent on the point of view adopted during the risk assessment. This is illustrated by table 2. It shows that the definition of the various risk parameters can vary from one type of risk to the other. The main differences reside in the intensive or extensive character of the dimensions. It stresses the fact that the reference system must be clearly defined prior to the assessment of the dimensions to avoid misunderstanding of the results, in terms of frequency or intensity. When the reference system is the community, the risk estimate is in a first approach the product of the risk generated by a single source by the number of hazard sources present in the community.

ELEMENTS AT RISK

The damage level depends on the number of vulnerable elements that can be hit by the hazardous phenomenon. An accident that would occur in a place where no vulnerable element (population, building, natural environment) is present would produce no damage at all. On the other hand, an accident occurring in a densely populated area will certainly produce a large number of fatalities if its intensity passes the lethal effect limit. An estimate of the elements at risk exposed to the effects of the accident is thus an essential aspect of the risk estimate. These elements are firstly the people: population, workers and users of the transportation system. But they can also be economic assets, such as industry or critical facilities. A typology of elements at risk is proposed. For each type, categories were defined, which are representative of the number elements at risk potentially exposed. For example, when considering the population, the area is characterised with the scale given in table 5. The community risk profile provides a list of questions to characterise the elements at risk. The final mark for the community is the maximum of all marks obtained for each type of element at risk.

Table 5. Scale for the characterisation of elements at risk: human beings exposed

Level	Description
1	Very low density area (Farmland, scattered houses), very few vulnerable elements exposed
2	Low density area (Individual dwellings, Village, quiet residential area), a few vulnerable elements exposed
3	Intermediate density area (Residential area), everal vulnerable elements exposed
4	High density area (Busy residential area), many vulnerable elements exposed
5	Very high density area (Urban area, centre of city, very active commercial zone), very large number of vulnerable elements exposed

VULNERABILITY

The vulnerability of a group of elements at risk characterises its capacity to resist or to undergo damages when submitted to a hazardous effect. For example, if a house has been reinforced, it may resist to a flash flooding. In the same way concrete houses may resist better to moderate overpressure than metallic structures. Vulnerability is thus a dimension of risk that has to be assessed. The reduction of vulnerability is among the measures that can be taken to reduce the risk.

Two types of vulnerabilities were considered: the technical vulnerability, or capacity of a given set of elements to resist to an accident and the social and economic vulnerability of the community.

For each of these themes, the vulnerability can be characterised from qualitative questions into a scale varying from 1 to 5. For the moment, the vulnerability of the community is considered to be the maximum of the vulnerabilities in each aspect. Other choices could be made as, for example to consider the average of vulnerabilities or some type of linear combination.

PREVENTION (OF THE HAZARDOUS PHENOMENON)

For some of the hazardous phenomena, it is possible to apply a prevention strategy aiming at reducing the probability of the phenomenon. The preventive measures are, for example, possible in the industry where specific safety devices or organisational measures can prevent the occurrence of failures susceptible to lead to an accident. In the risk community profile, it is generally not possible to assess the actual specific preventive measures but rather to consider if general prevention strategies are applied. These refer, for example, to the existence of a legislation and its enforcement or to the existence of local monitoring and alert systems dedicated to the early warning and intervention before a major accident occurs.

In some risk assessment methods, safety barriers are assessed in terms of level of confidence and reliability which has a direct quantitative impact on the probability of the accidental scenario. In the case of the community risk profile, it was impossible to establish such a quantitative link. Thus the level of prevention is calculated on a very simple basis: 1 if all prevention measures identified as possible are in place, 5 if none. No connection is made between the prevention level and the frequency level even if it is obvious that both are strongly dependent.

PROTECTION, MITIGATION

Protection and mitigation have the effect of reducing the intensity of the hazardous phenomenon that reaches the vulnerable element exposed. For example a mitigation device can be a protection dike against flooding or a reinforced wall to resist a potential blast effect from an explosion.

Specific intervention plans are also covered in the mitigation theme as well as measures aiming at reducing the vulnerability or preventing that it increases. For example, measures such as land use restriction or construction rules and standards are among the mitigation measures.

As for prevention, it is not possible to establish a quantitative scale for protection measures. The assessment is cumulative, from 5 when no protection measure is in place to 1 when all the possible protection measures are present.

EMERGENCY PREPAREDNESS

The emergency preparedness covers all the technical and organisational measures that contribute to the efficient intervention in case of an emergency. The emergency preparedness is the core of the APELL program. The assessment of this dimension in the community risk profile tool is done through a questionnaire that was developed in the framework of the APELL program [APELL 1988].

The emergency preparedness is assessed globally for all the community and all the hazards. The assumption was that the same organisation should be involved in the emergency response to any of the hazards and that if its global organisation is good, it should benefit all the situations. However, in each specific risk assessment sheet, questions are asked in the protection section to assess the specificity of the emergency response for one given hazard type.

RESILIENCE

The resilience characterises the capacity of a person or a community to recover after an accident. This capacity is related with various characteristics of the community, which are not discussed in the present paper. Among them are the existence of a disaster recovery planning, the access to knowledge, the economic capacity of the community, the health system, the learning capacity of the system, the local cohesion and the technical capacity of the community.

CONCLUSIONS AND PERSPECTIVES

The community risk profile is an attempt to build a guided preliminary risk assessment tool for a large variety of natural and technological risks using a common set of dimensions expressed in common scales. It provides the user with the list of questions to ease the assessment of each of these dimensions.

This paper has stressed the difficulties associated with the setting of common definitions and scales for the nine dimensions of risk and the solutions proposed in the Community Risk Profile. These difficulties should not hinder the fact that the community risk profile should be a very useful tool for reflection and risk awareness raising among risk managers, decision makers and stakeholders.

A first version of the tool was experimented for training of community risk managers in Morocco and Sri-Lanka and proved to be at first an efficient teaching support. It is now under revision by the experts of the UNEP APELL program to assess its capacity to be used by risk managers all around the world. The goal is to publish the tool by mid 2007.

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